

What is Claimed is:

1.           An electromagnetic flowmeter comprising:
  - 2               a measuring pipe through which a fluid to be
  - 3 measured flows;
  - 4               an electrode which is arranged in said
  - 5 measuring pipe and detects an electromotive force
  - 6 generated by a magnetic field applied to the fluid and
  - 7 flow of the fluid;
  - 8               a first exciting coil which is arranged
  - 9 separately from a plane, which includes said electrode
  - 10 and is perpendicular to a direction of an axis of said
  - 11 measuring pipe, and applies a first magnetic field
  - 12 having a first frequency to the fluid;
  - 13               a second exciting coil which is arranged on a
  - 14 side opposite to said first exciting coil with respect
  - 15 to the plane and applies, to the fluid, a second
  - 16 magnetic field obtained by amplitude-modulating a
  - 17 carrier having the first frequency by a modulated wave
  - 18 having a second frequency;
  - 19               a power supply section which supplies an
  - 20 exciting current to said first exciting coil and said
  - 21 second exciting coil;
  - 22               a signal conversion section which separates a
  - 23 component of the first frequency from the electromotive
  - 24 force detected by said electrode to obtain an amplitude,
  - 25 separates one of components of sum and difference

26 frequencies of the first and second frequencies from the  
27 electromotive force to obtain an amplitude, and obtains  
28 a ratio of the amplitudes; and  
29 a flow rate output section which calculates a  
30 flow rate of the fluid on the basis of the amplitude  
31 ratio obtained by said signal conversion section.

2. A flowmeter according to claim 1, wherein  
2 on the basis of the amplitude ratio  $R_{am}$   
3 obtained by said signal conversion section, a phase  
4 difference  $\theta 2$  between the carrier components of the  
5 first and second magnetic fields, and an amplitude  
6 modulation index  $m_a$  of the second magnetic field, said  
7 flow rate output section calculates the flow rate of the  
8 fluid by  $\alpha \times \omega 0 \{-8 \sin(\theta 2) + R_{am} m_a (16 - R_{am}^2 m_a^2)^{1/2}\} / \{8 +$   
9  $8 \cos(\theta 2) - R_{am}^2 m_a^2\}$  ( $\alpha$  is a coefficient).

3. An electromagnetic flowmeter comprising:  
2 a measuring pipe through which a fluid to be  
3 measured flows;  
4 an electrode which is arranged in said  
5 measuring pipe and detects an electromotive force  
6 generated by a magnetic field applied to the fluid and  
7 flow of the fluid;  
8 a first exciting coil which is arranged  
9 separately from a plane, which includes said electrode  
10 and is perpendicular to a direction of an axis of said

11 measuring pipe, and applies a first magnetic field  
12 having a first frequency to the fluid;  
13           a second exciting coil which is arranged on a  
14 side opposite to said first exciting coil with respect  
15 to the plane and applies, to the fluid, a second  
16 magnetic field obtained by amplitude-modulating a  
17 carrier having the first frequency by a modulated wave  
18 having a second frequency;  
19           a power supply section which supplies an  
20 exciting current to said first exciting coil and said  
21 second exciting coil;  
22           a signal conversion section which separates a  
23 component of the first frequency from the electromotive  
24 force detected by said electrode to obtain a first phase  
25 difference between the first exciting current supplied  
26 to said first exciting coil and the component of the  
27 first frequency separated from the electromotive force,  
28 and separates one of components of sum and difference  
29 frequencies of the first and second frequencies from the  
30 second exciting current supplied to said second exciting  
31 coil and separates one of the components of the sum and  
32 difference frequencies from the electromotive force to  
33 obtain a second phase difference for the same frequency  
34 between the component separated from the second exciting  
35 current and the component separated from the  
36 electromotive force; and  
37           a flow rate output section which calculates a

38 flow rate of the fluid on the basis of the first phase  
39 difference and the second phase difference obtained by  
40 said signal conversion section.

4. A flowmeter according to claim 3, wherein  
2 on the basis of the first phase difference  $\phi$   
3 or and the second phase difference  $\phi_{am}$ , which are  
4 obtained by said signal conversion section, the first  
5 frequency  $\omega_0$ , and a phase difference  $\theta_2$  between the  
6 carrier components of the first and second magnetic  
7 fields, said flow rate output section calculates the  
8 flow rate of the fluid by  $\alpha \times \omega_0 \tan(\pi/2 + \phi_{am} - \phi$   
9 or  $- \theta_2/2)$  ( $\alpha$  is a coefficient).

5. An electromagnetic flowmeter comprising:  
2 a measuring pipe through which a fluid to be  
3 measured flows;  
4 an electrode which is arranged in said  
5 measuring pipe and detects an electromotive force  
6 generated by a magnetic field applied to the fluid and  
7 flow of the fluid;  
8 a first exciting coil which is arranged  
9 separately from a plane, which includes said electrode  
10 and is perpendicular to a direction of an axis of said  
11 measuring pipe, and applies, to the fluid, a first  
12 magnetic field obtained by amplitude-modulating a  
13 carrier having a first frequency by a modulated wave

14 having a second frequency;  
15           a second exciting coil which is arranged on a  
16 side opposite to said first exciting coil with respect  
17 to the plane and applies, to the fluid, a second  
18 magnetic field obtained by amplitude-modulating the  
19 carrier having the first frequency by a modulated wave  
20 having the same frequency as that of the modulated wave  
21 and an opposite phase;  
22           a power supply section which supplies an  
23 exciting current to said first exciting coil and said  
24 second exciting coil;  
25           a signal conversion section which separates a  
26 component of the first frequency from the electromotive  
27 force detected by said electrode to obtain an amplitude,  
28 separates one of components of sum and difference  
29 frequencies of the first and second frequencies from the  
30 electromotive force to obtain an amplitude, and obtains  
31 a ratio of the amplitudes; and  
32           a flow rate output section which calculates a  
33 flow rate of the fluid on the basis of the amplitude  
34 ratio obtained by said signal conversion section.

6.           A flowmeter according to claim 5, wherein  
2           on the basis of the amplitude ratio  $R_{am}$   
3 obtained by said signal conversion section, a phase  
4 difference  $\theta_2$  between the carrier components of the  
5 first and second magnetic fields, and an amplitude

6 modulation index  $m_a$  of the first and second magnetic  
7 fields, said flow rate output section calculates the  
8 flow rate of the fluid by  $\alpha \times \omega_0 \{ R m_a \cos(\theta$   
9  $2/2) - 2 \sin(\theta 2/2) \} / \{ R m_a \sin(\theta 2/2) + 2 \cos(\theta 2/2) \}$  ( $\alpha$  is  
10 a coefficient).

7. An electromagnetic flowmeter comprising:  
2 a measuring pipe through which a fluid to be  
3 measured flows;  
4 an electrode which is arranged in said  
5 measuring pipe and detects an electromotive force  
6 generated by a magnetic field applied to the fluid and  
7 flow of the fluid;  
8 a first exciting coil which is arranged  
9 separately from a plane, which includes said electrode  
10 and is perpendicular to a direction of an axis of said  
11 measuring pipe, and applies a first magnetic field  
12 having a first frequency to the fluid;  
13 a second exciting coil which is arranged on a  
14 side opposite to said first exciting coil with respect  
15 to the plane and applies, to the fluid, a second  
16 magnetic field obtained by phase-modulating a carrier  
17 having the first frequency by a modulated wave having a  
18 second frequency;  
19 a power supply section which supplies an  
20 exciting current to said first exciting coil and said  
21 second exciting coil;

22 a signal conversion section which, when a  
 23 frequency corresponding to an integer multiple of the  
 24 second frequency is defined as a third frequency,  
 25 separates a component of the first frequency from the  
 26 electromotive force detected by said electrode to obtain  
 27 an amplitude, separates one of components of sum and  
 28 difference frequencies of the first and third  
 29 frequencies from the electromotive force to obtain an  
 30 amplitude, and obtains a ratio of the amplitudes; and  
 31 a flow rate output section which calculates a  
 32 flow rate of the fluid on the basis of the amplitude  
 33 ratio obtained by said signal conversion section.

8. A flowmeter according to claim 7, wherein  
 2 on the basis of the amplitude ratio  $R_{pm}$   
 3 obtained by said signal conversion section, the first  
 4 frequency  $\omega_0$ , a phase difference  $\theta_2$  between the  
 5 carrier components of the first and second magnetic  
 6 fields, a phase modulation index  $m_p$  of the second  
 7 magnetic field, and a Bessel function of fractional  
 8 order  $J_n(m_p)$  ( $n = 0$  or  $1$ ), said flow rate output section  
 9 calculates the flow rate of the fluid by  $\alpha \times [\omega$   
 10  $0\{-2J_0(m_p)\sin(\theta_2) + \{2J_0(m_p)^2 - J_0(m_p)^4 +$   
 11  $2J_0(m_p)^2 J_1(m_p)^2 R_{pm}^2 - 1 + 2J_1(m_p)^2 R_{pm}^2 - J_1(m_p)^4 R_{pm}^4\}^{1/2}\}]/\{J_0(m_p)^2$   
 12  $+ 1 + 2J_0(m_p)\cos(\theta_2) - J_1(m_p)^2 R_{pm}^2\}$  ( $\alpha$  is a coefficient).

9. An electromagnetic flowmeter comprising:

2                   a measuring pipe through which a fluid to be  
3   measured flows;

4                   an electrode which is arranged in said  
5   measuring pipe and detects an electromotive force  
6   generated by a magnetic field applied to the fluid and  
7   flow of the fluid;

8                   a first exciting coil which is arranged  
9   separately from a plane, which includes said electrode  
10   and is perpendicular to a direction of an axis of said  
11   measuring pipe, and applies, to the fluid, a first  
12   magnetic field obtained by phase-modulating a carrier  
13   having a first frequency by a modulated wave having a  
14   second frequency;

15                  a second exciting coil which is arranged on a  
16   side opposite to said first exciting coil with respect  
17   to the plane and applies, to the fluid, a second  
18   magnetic field obtained by phase-modulating the carrier  
19   having the first frequency by a modulated wave having  
20   the same frequency as that of the modulated wave and an  
21   opposite phase;

22                  a power supply section which supplies an  
23   exciting current to said first exciting coil and said  
24   second exciting coil;

25                  a signal conversion section which, when a  
26   frequency corresponding to an integer multiple of the  
27   second frequency is defined as a third frequency,  
28   separates a component of the first frequency from the



29 electromotive force detected by said electrode to obtain  
 30 an amplitude, separates one of components of sum and  
 31 difference frequencies of the first and third  
 32 frequencies from the electromotive force to obtain an  
 33 amplitude, and obtains a ratio of the amplitudes; and  
 34 a flow rate output section which calculates a  
 35 flow rate of the fluid on the basis of the amplitude  
 36 ratio obtained by said signal conversion section.

10. A flowmeter according to claim 9, wherein  
 2 on the basis of the amplitude ratio  $R_{pm}$   
 3 obtained by said signal conversion section, the first  
 4 frequency  $\omega_0$ , a phase difference  $\theta_2$  between the  
 5 carrier components of the first and second magnetic  
 6 fields, a phase modulation index  $m_p$  of the first and  
 7 second magnetic fields, and a Bessel function of  
 8 fractional order  $j_n(m_p)$  ( $n = 0$  or  $1$ ), said flow rate  
 9 output section calculates the flow rate of the fluid by  
 10  $\alpha \times \omega_0 [-\{J_0(m_p)^2 \cos(\theta_2) \sin(\theta_2) + J_1(m_p)^2 \sin(\theta_2) \cos(\theta_2)\} R_{pm}^2 + J_1(m_p)^2 \sin(\theta_2) R_{pm}^2 + J_0(m_p)^2 \sin(\theta_2)] +$   
 11  $2 [J_0(m_p) J_1(m_p) \{\cos(\theta_2) + 1\} R_{pm}] / \{2 J_0(m_p)^2 \cos(\theta_2) + J_0(m_p)^2$   
 12  $+ J_0(m_p)^2 \cos(\theta_2)^2 - J_1(m_p)^2 R_{pm}^2 + J_1(m_p)^2 \cos(\theta_2)^2 R_{pm}^2\}$  ( $\alpha$  is  
 13 a coefficient).  
 14

11. An electromagnetic flowmeter comprising:  
 2 a measuring pipe through which a fluid to be  
 3 measured flows;

4 an electrode which is arranged in said  
5 measuring pipe and detects an electromotive force  
6 generated by a magnetic field applied to the fluid and  
7 flow of the fluid;  
8 a first exciting coil which is arranged  
9 separately from a plane, which includes said electrode  
10 and is perpendicular to a direction of an axis of said  
11 measuring pipe, and applies a first magnetic field  
12 having a first frequency to the fluid;  
13 a second exciting coil which is arranged on a  
14 side opposite to said first exciting coil with respect  
15 to the plane and applies, to the fluid, a second  
16 magnetic field obtained by frequency-modulating a  
17 carrier having the first frequency by a modulated wave  
18 having a second frequency;  
19 a power supply section which supplies an  
20 exciting current to said first exciting coil and said  
21 second exciting coil;  
22 a signal conversion section which, when a  
23 frequency corresponding to an integer multiple of the  
24 second frequency is defined as a third frequency,  
25 separates a component of the first frequency from the  
26 electromotive force detected by said electrode to obtain  
27 an amplitude, separates one of components of sum and  
28 difference frequencies of the first and third  
29 frequencies from the electromotive force to obtain an  
30 amplitude, and obtains a ratio of the amplitudes; and

31 a flow rate output section which calculates a  
 32 flow rate of the fluid on the basis of the amplitude  
 33 ratio obtained by said signal conversion section.

12. A flowmeter according to claim 11, wherein  
 2 on the basis of the amplitude ratio  $R_{fm}$   
 3 obtained by said signal conversion section, the first  
 4 frequency  $\omega_0$ , a phase difference  $\theta_2$  between the  
 5 carrier components of the first and second magnetic  
 6 fields, a frequency modulation index  $m_f$  of the second  
 7 magnetic field, and a Bessel function of fractional  
 8 order  $J_n(m_f)$  ( $n = 0$  or  $1$ ), said flow rate output section  
 9 calculates the flow rate of the fluid by  $\alpha \times [\omega$   
 10  $0\{-2J_0(m_f)\sin(\theta_2) + \{2J_0(m_f)^2 - J_0(m_f)^4 +$   
 11  $2J_0(m_f)^2 J_1(m_f)^2 R_{fm}^2 - 1 + 2J_1(m_f)^2 R_{fm}^2 - J_1(m_f)^4 R_{fm}^4\}^{1/2}\}]/\{J_0(m_f)^2$   
 12  $+ 1 + 2J_0(m_f)\cos(\theta_2) - J_1(m_f)^2 R_{fm}^2\}$  ( $\alpha$  is a coefficient).

13. An electromagnetic flowmeter comprising:  
 2 a measuring pipe through which a fluid to be  
 3 measured flows;  
 4 an electrode which is arranged in said  
 5 measuring pipe and detects an electromotive force  
 6 generated by a magnetic field applied to the fluid and  
 7 flow of the fluid;  
 8 a first exciting coil which is arranged  
 9 separately from a plane, which includes said electrode  
 10 and is perpendicular to a direction of an axis of said

11 measuring pipe, and applies, to the fluid, a first  
12 magnetic field obtained by frequency-modulating a  
13 carrier having a first frequency by a modulated wave  
14 having a second frequency;  
15 a second exciting coil which is arranged on a  
16 side opposite to said first exciting coil with respect  
17 to the plane and applies, to the fluid, a second  
18 magnetic field obtained by frequency-modulating the  
19 carrier having the first frequency by a modulated wave  
20 having the same frequency as that of the modulated wave  
21 and an opposite phase;  
22 a power supply section which supplies an  
23 exciting current to said first exciting coil and said  
24 second exciting coil;  
25 a signal conversion section which, when a  
26 frequency corresponding to an integer multiple of the  
27 second frequency is defined as a third frequency,  
28 separates a component of the first frequency from the  
29 electromotive force detected by said electrode to obtain  
30 an amplitude, separates one of components of sum and  
31 difference frequencies of the first and third  
32 frequencies from the electromotive force to obtain an  
33 amplitude, and obtains a ratio of the amplitudes; and  
34 a flow rate output section which calculates a  
35 flow rate of the fluid on the basis of the amplitude  
36 ratio obtained by said signal conversion section.

14. A flowmeter according to claim 13, wherein  
 2 on the basis of the amplitude ratio Rfm  
 3 obtained by said signal conversion section, the first  
 4 frequency  $\omega_0$ , a phase difference  $\theta_2$  between the  
 5 carrier components of the first and second magnetic  
 6 fields, a frequency modulation index  $m_f$  of the first and  
 7 second magnetic fields, and a Bessel function of  
 8 fractional order  $j_n(m_f)$  ( $n = 0$  or  $1$ ), said flow rate  
 9 output section calculates the flow rate of the fluid by  
 10  $\alpha \times \omega_0 [-\{J_0(m_f)^2 \cos(\theta_2) \sin(\theta_2) + J_1(m_f)^2 \sin(\theta_2) \cos(\theta_2)\} Rfm^2 + J_1(m_f)^2 \sin(\theta_2) Rfm^2 + J_0(m_f)^2 \sin(\theta_2)] +$   
 11  $2 |J_0(m_f) J_1(m_f) \{ \cos(\theta_2) + 1 \} Rfm| ] / \{ 2 J_0(m_f)^2 \cos(\theta_2) + J_0(m_f)^2$   
 12  $+ J_0(m_f)^2 \cos(\theta_2)^2 - J_1(m_f)^2 Rfm^2 + J_1(m_f)^2 \cos(\theta_2)^2 Rfm^2 \}$  ( $\alpha$  is  
 13 a coefficient).